

3.0 Vadose Zone

D. G. Horton

Vadose zone monitoring, using leachate and soil-gas sampling, occurred at three areas on the Hanford Site in fiscal year (FY) 2007. Leachate and soil-gas monitoring continued at the Environmental Restoration Disposal Facility and the Solid Waste Landfill. Also, soil-gas monitoring at the carbon tetrachloride expedited-response-action site continued during FY 2007.

The Tank Farm Vadose Zone Project installed several direct push boreholes in the B, T, and U Tank Farms to support placement of the T-106 Interim Barrier, install electrodes for future geophysical surveys, and investigate unplanned releases. The Tank Farm Vadose Zone Project also completed surface geophysical exploration at Waste Management Area B-BX-BY to map subsurface contaminant distribution. Also, SM Stoller Corporation continued to map vadose zone uranium distribution at Waste Management Area B-BX-BY. Finally, work on a treatability test plan to investigate remediation in the Central Plateau's deep vadose zone began in FY 2007. These monitoring and characterization efforts are summarized in the following sections.

3.1 Leachate Monitoring at the Environmental Restoration Disposal Facility

R. L. Weiss

Washington Closure Hanford, LLC operates the Environmental Restoration Disposal Facility to dispose of radioactive and mixed waste generated during waste management and remediation activities at the Hanford Site. In FY 2007, Washington Closure Hanford, LLC published the results of groundwater and leachate monitoring and sampling at the Environmental Restoration Disposal Facility during the calendar year 2006 (WCH-189). The groundwater results are discussed in Section 2.9; this section summarizes the vadose zone results.

The Environmental Restoration Disposal Facility began operation in July 1996. Located between the 200 East and 200 West Areas (see Figure 2.9-1 in Section 2.9), the facility is currently operating four disposal cells. Throughout calendar year 2006, ~525,614 metric tons of remediation waste were disposed at the facility.

Each disposal cell was constructed with a double liner system to collect leachate resulting from water added as a dust suppressant and natural precipitation. The collected leachate is sent to the Effluent Treatment Facility. The liners deliver the leachate to sumps beneath the cells where it is sampled. A composite sample of leachate was collected in duplicate in June and December 2006 from the sumps associated with the upper liners of cells 1 through 4. The samples were analyzed for selected metals, anions, selected organic compounds, total dissolved solids, gross alpha, gross beta, and selected radionuclides. The purposes of the analyses are to provide data for leachate delisting analyses and to assess whether additional analytes should be added to the routine groundwater monitoring program at the Environmental Restoration Disposal Facility.

The composite leachate samples contained detectable concentration of common metals, anions, and mobile radionuclides. Constituents that were generally increasing

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in concentration include chromium, specific conductance, bromide, nitrate, gross alpha, and uranium. The following is a summary (from WHC-189) of those analytes with increasing trends:

- Chromium concentrations that previously were slowly increasing at a stable rate over time appear to have stabilized. The chromium concentration averaged ~29 µg/L in December 2006, down somewhat from 37 µg/L in December 2005.
- Specific conductance appeared to remain stable until December 2004, at which time a fairly significant increase was observed. The June 2006 values (average 2,740 µS/cm) were similar to the previous December 2005 samples, but the values increased to an average of 3,645 µS/cm in December 2006.
- Bromide was not detected in leachate samples until June 2004, and the concentration of bromide increased through June 2005. The June 2006 concentration was 1.1 mg/L.
- Nitrate concentrations had increased at a fairly steady rate through calendar year 2004 but appear to have decreased during 2005. Concentrations remained stable through 2006 at ~ 372 mg/L.
- Uranium concentrations have increased over the past 3 years and reached a new maximum concentration of 1,734 µg/L in December 2006.
- Nickel, which is monitored every 2 years, appears to be increasing. The average nickel concentration was 20.7 µg/L in December 2006.
- Potassium, which is monitored every 2 years, appeared to be increasing through 2004 but stabilized at 27,000 µg/L in December 2006.
- Total dissolved solids appear to be increasing through 2006. The average December 2006 total dissolved solids value was 2,320,000 µg/L.
- Gross alpha concentrations have increased over the past 3 years with an average December concentration of 1,200 pCi/L. The increase in gross alpha parallels the increase in uranium and most of the alpha activity is probably due to uranium.
- Gross beta concentrations have increased over the past 3 years with an average December concentration of 932 pCi/L. Specific beta emitters responsible for the gross beta activity are not known for certain.

Groundwater monitoring data for nickel, gross alpha, gross beta, and uranium were examined to determine whether the leachate from the Environmental Restoration Disposal Facility has affected groundwater. In all cases, groundwater concentrations for these constituents remained stable. Based on this comparison, the data suggest that the Environmental Restoration Disposal Facility leachate has not affected groundwater.

3.2 Leachate and Soil-Gas Monitoring at the 600 Area Central Landfill

Summarized by D. G. Horton

The Solid Waste Landfill is a disposal facility in the center of the Hanford Site (part of the Central Landfill illustrated on Figure 2.1-1 in Section 2.1). The Solid Waste Landfill covers an area of ~26.7 hectares and began operating in 1973 to

receive non-hazardous, nonradioactive sanitary waste generated from Hanford Site operations. The Solid Waste Landfill stopped receiving waste in 1996 and an “interim cover” consisting of 0.6 to 1.2 meters of soil was placed over all trenches. Current monitoring at the 600 Area Central Landfill consists of sampling groundwater, soil gas, and leachate. Recent groundwater monitoring results are discussed in Section 2.11. This section summarizes leachate and soil-gas monitoring results. The results are forwarded annually to Washington State Department of Ecology (Ecology) and the most recent report^(a) covers the period July 2006 to June 2007.

The 600 Area Central Landfill consists of single trenches and double trenches. One of the double trenches overlies a lined basin lysimeter designed to collect leachate generated by infiltration through the overlying refuse. (All other trenches are unlined.) This lysimeter covers an area of ~88 square meters. A discharge pipe continuously drains leachate by gravity flow from the basin to a nearby collection pump. However, leachate collected from this lysimeter may not be representative of leachate drainage throughout the entire landfill area because the lysimeter only collects leachate from one of the double trenches and is installed under one of the newer trenches built after implementation of regulations that restrict land disposal practices. Still, the lysimeter provides some indication of the rate of infiltration and some of the contaminants that may be released to the vadose zone beneath the site.

Leachate is collected from the basin lysimeter every 10 to 14 days. Figure 3.0-1 shows the rate of leachate generated over the past 9 years. Prior to calendar year 2003, the generation rate was consistently between 4 to 8 liters/day. However, during the July 2003 through June 2004 and July 2004 through June 2005 reporting periods, the generation rates increased significantly to ~19 liters/day. This increase mainly was attributed to above average rainfall recorded at the Hanford Site

For the reporting period between July 2006 through June 2007, a total of ~3,165 liters of leachate was generated, for a daily average during the year of 8.7 liters (Figure 3.0-1). This was about a 35% increase in leachate generation from the previous year, when the daily average was ~6.4 liters/day. This increase is attributed mainly to higher than normal precipitation recorded at the Hanford Site during October through December 2006. The Hanford Meteorological Station recorded 8.2 centimeters of precipitation between October and December 2006.

Leachate is sampled and tested quarterly for indicator parameters listed in WAC 173-304-490 and annually for site-specific constituents, which cover a complete range of metals and organics. Concentrations measured during July 2006 through June 2007 are similar to previous concentrations and did not identify any areas of concern. Some of the indicator parameters and some organic constituents and metals in the leachate continued to be above WAC 173-200 groundwater quality criteria and/or drinking water standards established in WAC 246-290-310. See Section 2.11.3.8 for a discussion of groundwater at the 600 Area Central Landfill. Table 3.0-1 shows analytical results for key constituents in the 600 Area Central Landfill leachate.

Soil gas at the 600 Area Central Landfill is monitored to demonstrate that the air quality performance standards are met. Soil-gas monitoring at the Solid Waste Landfill uses eight shallow monitoring stations located around the perimeter of the landfill. Each station consists of two soil-gas probes at depths of ~2.75 and 4.6 meters. Soil gas is monitored quarterly to determine concentrations of carbon

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and tested quarterly.***

(a) Letter FH-0702400 from CM Murphy (Fluor Hanford, Inc., Richland, Washington) to DA Brockman (U.S. Department of Energy, Richland, Washington), PHMC Section C.4.2 - Submittal of Solid Waste Landfill Annual Monitoring Report, dated September 26, 2007.

dioxide, methane, and several key volatile organic compounds. During the reporting period, between July 2006 and June 2007, results were consistent with results for soil-gas monitoring during previous years. The volatile organic constituents were at or below the detection limits. Methane concentrations remain low or, for the most part, are not detected. Carbon dioxide concentrations continue to be consistent with previous data. Carbon dioxide concentrations are lower when atmospheric pressure is rising and higher when atmospheric pressure is low.

3.3 Carbon Tetrachloride Monitoring and Remediation

V. J. Rohay

Soil-vapor extraction is being used to remove carbon tetrachloride from the vadose zone in the 200 West Area. The U.S. Environmental Protection Agency (EPA) and Washington State Department of (Ecology) authorized DOE to initiate this remediation in 1992 as a *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) expedited response action. The following discussion summarizes fiscal year (FY) 2007 activities associated with the carbon tetrachloride removal. A report containing detailed results of FY 2007 activities will be published in FY 2008. For descriptions of past work, see BHI-00720, WMP-17869, WMP-21327, WMP-26178, WMP-30426, SGW-33746, and Section 3.1.3 in PNNL-16346. SGW-33746 describes the soil-vapor extraction system and the well fields. See Figure 3.0-2 for locations of vapor extraction wells.

The 14.2-cubic-meter/minute soil-vapor extraction system was operated at the 216-Z-9 well field from March 29 through August 7, 2007. The soil-vapor extraction system was operated at the 216-Z-1A well field from August 15 through September 28, 2007. The system was maintained in standby mode from September 30, 2006, through March 29, 2007. The 28.3- and 42.5-cubic-meter/minute soil-vapor extraction systems did not operate and were not maintained during FY 2007. Temporarily suspending soil-vapor extraction operations at each well field allows the carbon tetrachloride concentrations to recharge and be more economically extracted when operations resume.

To track the effectiveness of the remediation effort, soil-vapor concentrations of carbon tetrachloride were monitored at the inlet to the soil-vapor extraction system and at individual online extraction wells during the 6-month operating period. To assess the impact of the soil-vapor extraction system on subsurface concentrations, soil-vapor concentrations of carbon tetrachloride were monitored at off-line wells and probes during the entire fiscal year.

Remediation efforts during FY 2007 also included passive soil-vapor extraction.

3.3.1 Soil-Vapor Extraction

Soil-vapor extraction to remove carbon tetrachloride from the vadose zone resumed March 29, 2007, at the 216-Z-9 well field. Initial extraction was from wells close to the 216-Z-9 trench. As extraction continued, additional wells close to the trench and farther away from the trench were brought online. Extraction wells open near the less-permeable Cold Creek unit, where the highest carbon tetrachloride concentrations have consistently been detected in the past, were selected to optimize mass removal of contaminant. Extraction wells open near the groundwater also were selected. Three narrow-diameter wells (C4937, C4938, C5340) installed using a

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direct-push technology on the south side of the 216-Z-9 trench as part of the remedial investigation for the 200-PW-1 Operable Unit, were brought online in June 2007. During the 18 weeks of extraction in FY 2007, the maximum carbon tetrachloride concentration measured at the soil-vapor extraction system inlet was ~94 ppmv on the first day of operation (Figure 3.0-3). This concentration was higher than the maximum concentration (~41 ppmv) measured when the soil-vapor extraction system last operated at this site in 2006. The maximum concentration of carbon tetrachloride measured after the first day of operation was 36 ppmv.

Soil-vapor extraction resumed August 15, 2007, at the 216-Z-1A well field. Online wells were selected within the perimeter of the 216-Z-1A tile field. Extraction wells open near the less-permeable Cold Creek unit, where the highest carbon tetrachloride concentrations have consistently been detected in the past, were selected to optimize mass removal of contaminant. Initial carbon tetrachloride concentrations measured at the soil-vapor extraction inlet during the first week of operation were 0 ppmv, most likely as a result of dilution caused by leaks in the system. Following repairs to the system gaskets, carbon tetrachloride concentrations measured at the soil-vapor extraction inlet during the second week of operation were ~16 ppmv (Figure 3.0-3). This concentration was comparable to the maximum concentration (15 ppmv) measured when the soil-vapor extraction system last operated at this site in 2006.

As of September 2007, ~79,200 kilograms of carbon tetrachloride had been removed from the vadose zone since extraction operations started in 1991 (Table 3.0-2). The mass of carbon tetrachloride removed in FY 2007 was 280 kilograms. The performance evaluation report (SGW-33746) provides the amounts of carbon tetrachloride removed per year between 1991 and 2006.

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3.3.2 Monitoring at Off-Line Wells and Probes

During FY 2007, soil-vapor concentrations of carbon tetrachloride were monitored near the ground surface, near the Cold Creek unit (~40 meters below ground surface [bgs]), and near groundwater (~66 meters bgs). Soil-vapor concentrations were monitored near the ground surface and groundwater to evaluate whether non-operation of the soil-vapor extraction system negatively affects the atmosphere or groundwater. The maximum concentration detected near the ground surface (between 2 and 10 meters bgs) was 8 ppmv. Near the groundwater (between 53 and 66 meters bgs), the maximum concentration was 16 ppmv.

Soil-vapor concentrations also were monitored above and within the Cold Creek unit to provide an indication of concentrations that could be expected during restart of the soil-vapor extraction system. The maximum concentration detected near the Cold Creek unit (between 25 and 44 meters bgs) was 262 ppmv in soil-vapor probe CPT-28 (27 meters bgs) ~90 meters south of the 216-Z-9 trench. This location may be beyond the zone of influence of the soil-vapor extraction system. Within the 216-Z-9 well field, the maximum carbon tetrachloride concentration detected near the Cold Creek unit was 24 ppmv at two locations: soil-vapor probe CPT-24 and well 299-W15-216 (both 36 meters bgs). North of the 216-Z-9 trench ~200 meters, the maximum carbon tetrachloride concentration detected was 46 ppmv at soil-vapor probe CPT-9A (15 meters bgs).

At the 216-Z-1A well field, the maximum carbon tetrachloride concentration detected near the Cold Creek unit was 131 ppmv at well 299-W18-248 (40 meters bgs).

The maximum carbon tetrachloride concentrations detected in the vadose zone overlying the Cold Creek unit (between 11 and 23 meters bgs) were 193 ppmv at soil-vapor probe CPT-21A, which may be beyond the zone of influence of the soil vapor extraction system, and 191 ppmv at well C4937 (both 20 meters bgs) near the 216-Z-9 trench.

The temporary suspension of soil-vapor extraction in FY 2007 appears to have caused minimal detectable vertical transport of carbon tetrachloride through the soil surface to the atmosphere. This interpretation is supported by data that show carbon tetrachloride concentrations did not increase significantly at the near-surface monitoring probes. In addition, suspending operations of the soil-vapor extraction system appears to have had no negative impact on groundwater quality, because carbon tetrachloride concentrations did not increase significantly near the water table during that time.

3.3.3 Passive Soil-Vapor Extraction

Passive soil-vapor extraction is a remediation technology that uses naturally induced pressure gradients between the subsurface and the ground surface to drive soil vapor to the surface. In general, falling atmospheric pressure causes subsurface vapor to move to the atmosphere through wells, whereas rising atmospheric pressure causes atmospheric air to move into the subsurface. Passive soil-vapor extraction systems are designed to use this phenomenon to remove carbon tetrachloride from the vadose zone.

Passive soil-vapor extraction systems were installed at the end of FY 1999 at eight boreholes that are open near the vadose-groundwater interface at the 216-Z-1A/216-Z-12/216-Z-18 well field. The passive systems are outfitted with check valves that only allow soil-vapor flow out of the borehole (i.e., one-way movement), and canisters holding granular activated carbon that adsorbs carbon tetrachloride upstream of the check valves before the soil vapor is vented to the atmosphere. The check valve prohibits flow of atmospheric air into the borehole during a reverse barometric pressure gradient, which tends to dilute and spread carbon tetrachloride vapors in the subsurface.

The wells are sampled periodically upstream of the granular activated carbon canisters when atmospheric pressure is falling and the wells are venting. The maximum carbon tetrachloride concentrations measured at the four wells (299-W18-6, 299-W18-7, 299-W18-246, and 299-W18-252) in the vicinity of the 216-Z-1A tile field ranged from 12 to 39 ppmv. The maximum carbon tetrachloride concentrations measured at the four wells (299-W18-10, 299-W18-11, 299-W18-12, and 299-W18-247) in the vicinity of the 216-Z-18 crib ranged from 1 to 14 ppmv.

3.4 Tank Farm Vadose Zone Activities

J. G. Field and D. A. Myers

The Vadose Zone Integration Program is responsible for implementing the Tank Farm RCRA Corrective Action Program through field characterization, laboratory analyses, technical analyses, risk assessment for past tank leaks, and installation of interim measures that will reduce the threat from contaminants until permanent solutions can be found. In FY 2007, the Vadose Zone Integration Program installed several boreholes for soil sampling and geophysical logging at several tank farms and completed surface geophysical surveys at Waste Management Area B-BX-BY.

The temporary suspension of soil-vapor extraction in FY 2007 appears to have caused minimal transport of carbon tetrachloride through the soil to the atmosphere and appears to have had no negative impact on groundwater quality.

3.4.1 Direct Push Boreholes and Sampling

The hydraulic hammer unit was deployed in three tank farms during FY 2007 to evaluate subsurface contamination in the vadose zone. Several pushes were made in the B Tank Farm to investigate unplanned release sites associated with diversion boxes in that farm. The hydraulic hammer unit was deployed in the T Tank Farm to place vadose zone monitoring equipment in support of the T-106 interim barrier placement. In the U Tank Farm, the hydraulic hammer unit was deployed at 10 sites identified from previous investigations as having potentially anomalous distribution of resistivity (RPP-RPT-31557), and from historical records of tank leaks (RPP-15808). Table 3.0-3 provides the locations where direct push was used in single-shell tank farms during FY 2007. The table also shows the number of probe holes, total meters drilled, total meters geophysically logged, the number of samples taken, and the number of electrodes impacted at each site.

A relatively new application was made in the U Tank Farm deployment. At this site a multi-level sampler, developed for investigation of the Plutonium Finishing Plant trenches, was used to collect samples of potentially contaminated sediments for laboratory analysis. In addition, the hydraulic hammer unit was used to place deeply buried electrodes at each of the 10 investigated sites. These electrodes will be used during a future full-scale deployment of Surface Geophysical Exploration in the U Tank Farm.

Analyses of the samples collected during the hydraulic hammer unit deployments are being used in the Waste Management Area U Field Investigation Report (to be released as RPP-35845) and the RCRA Field Investigation Report that are scheduled to be published by January 2008.

3.4.2 Surface Geophysical Exploration

Surface geophysical exploration, a combination of surface deployed geophysical techniques, was applied in Waste Management Area B-BX-BY (RPP-RPT-34690) during FY 2007. In addition, reports about the FY 2006 field application of surface geophysical exploration in Waste Management Areas C (RPP-RPT-31558) and U (RPP-RPT-31557) were released during the fiscal year. The primary tool applied through surface geophysical exploration is pole-pole electrical resistivity; other tools include electro-magnetic induction, magnetic gradiometry, and ground-penetrating radar. These latter tools are used to help define the presence and distribution of buried infrastructure, so that those features may be taken into account during the analysis of resistivity data. The depth to which the resistivity measurements interrogate the subsurface is determined by the distance between electrode pairs (the further apart, the deeper the interrogation). Because resistivity is an indirect measure of several subsurface phenomena (e.g., moisture distribution, saline contaminants, or soil texture), the more separated the electrode pairs, the lower the resolution of the analysis. The resistivity data are mathematically analyzed through a process known as inversion to provide a best estimate of the distribution of resistivity anomalies. Surface geophysical exploration provides a means of extrapolating direct measurements taken by sampling, logging, or other means to provide a cost-effective overview of large areas that may have been impacted by a variety of waste management practices.

In Waste Management Area B-BX-BY (RPP-RPT-34690), the surface geophysical exploration analyses point to several regions worthy of further characterization using more conventional approaches such as drilling. Figure 3.0-4 provides an isometric, composite view of the waste management area. The figure shows areas of high

A hydraulic hammer is a hydraulic percussion drilling device used for driving steel pipe into the ground to collect samples or place monitoring equipment into the vadose zone.

The analysis of the surface geophysical exploration data is being used to determine the locations of several groundwater monitoring wells that will be drilled during FY 2008 and beyond.

conductance (low resistivity) in the vadose zone which probably correspond to areas of high concentrations of nitrate and associated contaminants.

The analysis of the surface geophysical exploration data is being used to direct the locations of several groundwater monitoring wells to be drilled during FY 2008 and beyond. Soil samples collected during the drilling activities will be analyzed and then used to further refine the numerical analysis of the already collected surface geophysical exploration data. Each piece of direct data can be used to further constrain the inversion analysis of the resistivity data, thereby providing an ever increasing resolution to the distribution of subsurface contamination.

3.5 Geophysical Logging

R. McCain

Radiation measurements have been taken in boreholes since the early days of the Hanford Site to detect manmade radionuclides in the subsurface. Logging at the Hanford Site is currently performed by SM Stoller Corporation (Stoller) under subcontract to the Hanford Site contractors.

Originally, the objective of the Hanford Geophysical Logging Project was to determine the nature and extent of subsurface contamination in the vicinity of the single-shell tank farms and to provide a baseline against which subsequent measurements could be compared. That effort was completed in 2000. Subsequent to completion of the initial tank farm effort, the Radionuclide Assessment System was developed for use by tank farms personnel, with support from Stoller. Use of the Radionuclide Assessment System in tank farms and comparison of new logs with the baseline logging is presently focused on retrieval support. Radionuclide Assessment System and moisture logging for retrieval is performed at the start and end of retrievals and when significant moisture changes are observed. Drywell logging requirements in support of waste retrieval operations are defined in Tank Waste Retrieval Work Plans and Process Control Plans. Additional tank farm logging will be addressed as part of Tank Farm Corrective Actions and integration between Tank Farm and Central Plateau contractors.

After completion of the original tank farm logging in 2000, the vadose zone characterization project then was established to log existing boreholes in or near waste sites in the Hanford 200 Areas. Stoller provides geophysical logging services in support of well decommissioning, remedial investigation efforts by other contractors, and the groundwater monitoring program. Borehole logs are provided directly to DOE and the Hanford Site contractors. They are also available via the internet at <http://www.hanford.gov/cp/gpp/data/gpl.cfm>. The logs are incorporated into data sets and reports for individual projects and will not be discussed in this section. This section focuses on logging systems currently in use, detection of manmade uranium, and uranium in the 200-BP-5 Groundwater Operable Unit.

3.5.1 Logging Systems in Use at Hanford

In 2007, the Hanford Geophysical Logging Project operated three logging trucks, with various logging instruments, i.e., sondes. Each combination of a logging truck and sonde is considered a logging system, and each logging system is individually calibrated. Calibrations are performed annually, or after any repairs or modifications to either the equipment or the logging sonde. Currently available logging systems include the following:

The original Hanford Geophysical Logging Project was completed in 2000. Currently, boreholes in or near waste sites at the 200 Areas are being logged to gather data that can help well decommissioning, remedial investigations, and groundwater monitoring.

- High-resolution spectral gamma logging systems, including the spectral gamma logging system and the high rate logging system. These systems collect high-resolution gamma energy spectra specific to individual gamma emitting radionuclides. The spectral gamma logging system can also be run in total gamma mode, where a shorter count time is used. Energy spectra also are collected and may be analyzed if necessary.
- Neutron moisture logging systems.
- The slim hole logging system, which includes total gamma logs, conventional spectral gamma, and neutron moisture logs - all of which are configured to run in boreholes with inner diameters as small as 4.4 centimeters.
- Passive neutron logging system.

Table 3.0-4 lists currently available logging systems and provides basic analytical performance requirements for typical logging applications.

In addition to the logging systems mentioned above, Stoller has developed and deployed both radionuclide assessment and monitoring systems for use by tank farms personnel. The radionuclide assessment system uses a series of three sodium iodide detectors with limited spectral capability to conduct routine drywell monitoring in the single-shell tank farms. Results are compared against previous logs and baseline data to detect any changes that might indicate a tank leak or contaminant migration. The radionuclide monitoring system uses a neutron moisture log and hybrid gamma detector system (sodium iodide detector and two pairs of Geiger-Mueller detectors) to simultaneously measure moisture content and gross gamma activity in dry wells near tanks undergoing waste retrieval operations.

3.5.2 Detection of Uranium in the Vadose Zone at 200-BP-5 Groundwater Operable Unit

Wells 299-E33-18, 299-E33-41, and 299-E33-45, located in the source operable units above the 200-BP-5 Groundwater Operable Unit, were originally logged as part of the baseline characterization effort in 2001 to 2002 (see Figure 2.10-1 for location of wells at Waste Management Area B-BX-BY). Uranium-238 logs from these wells were presented and discussed in PNNL-16346. Identification and quantification of manmade uranium is discussed in HGP-LDR-028. Log results identified a plume of manmade uranium, which appeared to be extending downward and to the east-northeast from the general vicinity of tank BX-102, intersecting groundwater in the vicinity of well 299-E33-18. (Sobczyk et al. 2003).

Evaluation of historical log data indicates that uranium-238 plume had arrived at well 299-E33-18 sometime between 1992 and 1997 (Figure 3.0-5), which coincides with the first report of uranium-238 in groundwater samples in early 1993. The 1997 log indicated a maximum uranium-238 concentration of 439 pCi/g at 72.5 meters bgs. The maximum concentration had increased to 1,237 pCi/g in 2006 and to 1,533 pCi/g in 2007 (both at 71.9 meters bgs). This increase is substantially greater than the counting error or error associated with logging system efficiency. Therefore, it is considered to represent a definite increase in uranium-238 in the deep vadose zone at well 299-E33-18. In well 299-E33-41, the maximum uranium concentration in FY 2007 was 715 pCi/g, compared to 777 pCi/g in 2006. In addition to uranium-238, uranium-235 was also detected, although at much lower concentrations. See Sections 2.10.1.6 and 2.10.3.1 for discussions of uranium in groundwater at Waste Management Area B-BX-BY.

Geophysical logging at Waste Management Area B-BX-BY indicates an increase of uranium in the deep vadose zone.

3.6 Deep Vadose Zone Treatability Test Plan

S. W. Petersen

Work on a treatability test plan for investigating remediation in the Central Plateau's deep vadose zone began in FY 2007. When submitted, this plan will satisfy the Tri-Party Agreement Milestone M-015-50, "Submit a Treatability Test Work Plan for Deep Vadose Zone Technetium and Uranium to Ecology and EPA." This milestone is due by December 31, 2007. The project team contributing to this plan includes members from the DOE Richland Operation Office and Office of River Protection, Fluor Hanford, Inc., Pacific Northwest National Laboratory, and CH2M HILL Hanford Group, Inc. Fluor Hanford, Inc. is responsible for the overall integration and production of the plan. The activities that will be performed to select a deep vadose zone remedy will satisfy the purposes of both CERCLA and RCRA statutory programs.

The objective of this treatability test plan for technetium-99 and uranium is to provide a strategy to evaluate specific vadose zone technologies for deep vadose zone remediation.

The objective of this treatability test plan for technetium-99 and uranium is to provide a roadmap, including identification of preferred technologies as well as plans and schedules for field testing those technologies. This effort, once implemented, will be used to support remedy selection and post-remedial decision design, deployment, and operation of remediation technologies in the Central Plateau including the following:

- Remediation of contaminated soil and groundwater.
- Closure of tank farms.
- Closure of cribs and trenches.

The treatability test plan framework will include two primary phases. The first phase will focus on conducting laboratory work and numerical modeling to address uncertainties associated with technology functioning and employing the technology in the deep vadose zone. The second phase will involve the large-scale design and implementation of treatability testing in the field at carefully selected locations. These Phase 2 tests will be conducted with one or more technologies depending on the success of Phase 1 testing. A schedule for Phase 2 is in the Treatability Test Plan. The test plan focuses on technetium-99 and uranium as directed by Tri-Party Agreement Milestone M-015-50. These contaminants are mobile in the subsurface environment, have been detected at high concentration deep in the vadose zone, and at some locations have reached groundwater. Testing technologies for remediation of technetium-99 and uranium will also provide information relevant to other contaminants in the vadose zone.

Figure 3.0-1 Analytical Results for Key Constituents in Leachate at the 600 Area Central Landfill

Parameter ^(a)	Results by Quarter				GWQC ^(b)	MCL ^(c)
	3rd 2006	4th 2006	1st 2007	2nd 2007		
Indicator Parameters						
Ammonia as N (mg/L)	0.330	0.340	0.292	NT	NA	NA
Chemical oxygen demand (mg/L)	222	220	208	204	NA	NA
Dissolved iron (µg/L)	87.9	9,850	8,870	6,400	300	300
Dissolved manganese (µg/L)	1,580	1,590	1,540	1,295 ^(d)	50	50
Dissolved zinc (µg/L)	187	40.5	109	155 ^(e)	5,000	5,000
pH	7.35	6.74	6.89	7.32	6.5-8.5	NA
Specific conductance (µS/cm)	1,680	1,860	1,920	2,000	NA	700
Total organic carbon (mg/L)	701	100	76.5	275	NA	NA
Site-Specific Parameters						
1,1,1-Trichloroethane (µg/L)	<1.0	NT	NT	<1.0	200	200
1,1-Dichloroethane (µg/L)	<1.0	NT	NT	<1.0	1.0	NA
1,4-Dichlorobenzene (µg/L)	6.5 ^(f)	NT	NT	4.15 ^(g)	4	NA
1,4-Dioxane (µg/L)	<25.0	NT	NT	<20.0	7	NA
Arsenic (µg/L)	29.3	NT	NT	20.1	0.05	10
Barium (µg/L)	519	NT	NT	452	1,000	2,000
Cadmium (µg/L)	<0.100	NT	NT	<0.100	10	5
Carbon tetrachloride (µg/L)	<1.0	NT	NT	<1.0	0.3	5
Chloride (mg/L)	210	191	192	199	250	25
Chloroform (µg/L)	<1.0	NT	NT	<1.0	7.0	NA
Copper (µg/L)	1.60	NT	NT	1.03	1,000	NA
Fluoride (mg/L)	<0.145	<0.0315	<0.321	0.207	4	4
Methylene chloride (µg/L)	<1.0	NT	NT	1.25 ^(h)	5	NA
Nickel (µg/L)	110	NT	NT	92.9	NA	100
Selenium (µg/L)	2.58	NT	NT	2.15	10	50
Sulfate (mg/L)	5.66	7.67	6.32	7.77	250	25
Tetrachloroethene (µg/L)	<1.0	NT	NT	<1.0	NA	NA
Total dissolved solids (mg/L)	1,460	NT	NT	1,380	500	500 ⁽ⁱ⁾
Total organic halides (µg/L)	NT	NT	NT	846	NA	NA
Trichloroethene (µg/L)	<1.0	NT	NT	<1.0	NA	NA

(a) Units as provided in analytical results report.

(b) Groundwater quality criteria from WAC 173-200.

(c) Maximum contaminant levels from WAC 246-290.

(d) Average result from two samples; one sample result was 1,200 µg/L and one sample result was 1,390 µg/L.

(e) Average result from two samples; one sample result was 120 µg/L and one sample result was 190 µg/L.

(f) Average result from two samples; one sample result was <1.0 µg/L and one sample result was 12.0 µg/L.

(g) Average result from two samples; one sample result was <1.0 µg/L and one sample result was 7.3 µg/L.

(h) Average result from two samples; one sample result was <1.0 µg/L and one sample result was 1.50 µg/L.

(i) Required only when specific conductivity exceeds 700 µS/cm.

NA = Not applicable.

NT = Not tested.

Table 3.0-2. Carbon Tetrachloride Inventory Removed by Vaport Extraction from Primary Disposal Sites

Well Field	Estimated Mass Discharged, 1955 to 1973 ^(a) (kg)	Estimated Mass Lost to Atmosphere, 1955 to 1990 ^(b) (kg)	Mass Removed Using Soil-Vapor Extraction, 1991 to September 2007 (kg)
216-Z-1A	270,000	56,700	24,667 ^(c)
216-Z-9	130,000 to 480,000	27,300 to 100,800	54,497
216-Z-18	170,000	35,700	—
Total	570,000 to 920,000	119,700 to 196,800	79,164
(a) Based on DOE/RL-91-32. (b) Based on WHC-SD-EN-TI-101. (c) Includes mass removed from 216-Z-18 site; reported as a combined value because the well fields overlap.			

Table 3.0-3. Hydraulic Hammer Deployment, FY 2007

Tank Farm	Total days	No. of Probes	Total meters drilled	Total meters logged		No. of Samples	No. of Electrodes
				Gross Gamma	Neutron Moisture		
T	64	23	425	231	66	9	2
B	29	12	153	130	56	4	4
U	107	21	550	313	304	23	10
Totals	224	56	1,138	674	426	36	16

Table 3.0-4. Analytical Performance Requirements for Geophysical Logging Methods^(a)

Parameter	Method	Parameter Reported	Minimum Borehole Inner Diameter	Logging Speed	Target Detection Limit ^(b)	Precision ^(c)	Quality Control	Notes
Gamma activity	SGLS ^(d)	Counts per second (cps),	10 cm	0.30480 m/min	Background + 2σ	< 2%	Pre-run and post-run verification	Does not identify source radionuclide and may be misleading
	(Total gamma)	% dead time					10% repeat section	
	SHLS ^(e)	cps or HGU	4.44 cm	0.60960 m/min		Depends on count time & activity	Verification & 10% repeat section	
	(NaI ^(f) & GMS ^(g))							
¹³⁷ Cs, ⁶⁰ Co	Spectral gamma (NaI)	KUT ^(h) ¹³⁷ Cs, ⁶⁰ Co	4.44 cm	0.30480-0.60960 m/min	10 - 20 pCi/g	+/- 20%	Verification and 10% repeat section	Energy resolution 30 to 50 keV: unable to resolve gamma lines for many radionuclides
Fission and activation products	SGLS (HPGe ⁽ⁱ⁾)	KUT & manmade radionuclides, (pCi/g), total gamma (cps) & dead time (%)	10 cm	2.438 - 9.144 m/hr	< 1 pCi/g	+/- 5-10%	Pre-run and post-run verification	Energy resolution 2-5 keV allows identification of characteristic decay gammas.
	HRLS ^(j) (HPGe)		10 cm		(depending on radionuclide)		10% repeat section	Minimum Detectable Activity and counting error are also reported.
Manmade uranium ^{234m} Pa	SGLS (HPGe)		10 cm		10-20 pCi/g			
					10,000 - 50,000 pCi/g			
					(1 pCi/g for ²³⁷ Np)			
TRU ^(k) ²³⁹ Pu, ²⁴¹ Am, ²⁴¹ Pu, ²³⁷ Np								
⁹⁰ Sr	SGLS (HPGe)	Qualitative indicator		> 500 - 1000 pCi/g	Qualitative		Bremsstrahlung associated with 2.3 MeV beta from ⁹⁰ Y daughter.	
TRU	PNLS ^(l)	cps	10 cm	0.30480 m/min	Qualitative only	Pre-run and post-run check	Dominant source of neutrons is alpha, n reaction; spontaneous fission is minor component.	
	(³ He detector)						Possible interference in high gamma activity	

Table 3.0-4. (contd)

Parameter	Method	Parameter Reported	Minimum Borehole Inner	Logging Speed	Target Detection Limit ^(b)	Precision ^(c)	Quality Control	Notes
Volumetric moisture content	NMLS ^(m)	cps	4.44 - 10 cm	0.30480 m/min	0.5 to 1 volume %	+/- 10% (of count rate)	Pre-run and post-run verification, 10% repeat section	Calibrations exist for 15.24-cm and 20.32-cm boreholes
	²⁴¹ Am-Be	Volume % moisture						
	(³ He detector)							
(a) All logging systems subject to annual calibration and daily source checks.								
(b) Target detection limit based on typical logging parameters and minimal interference.								
(c) Assuming typical background count rate and borehole environment.								
(d) Spectral gamma logging system.								
(e) Slim hole logging system.								
(f) Sodium iodide (scintillator) detector								
(g) Geiger-Mueller detector.								
(h) KUT refers to potassium, uranium and thorium as naturally occurring radionuclides.								
(i) High-purity germanium (solid state) detector.								
(j) High rate logging system: typically run where SGLS dead time exceeds 40%.								
(k) Transurranic radionuclides.								
(l) Passive neutron logging system.								
(m) Neutron moisture logging system.								

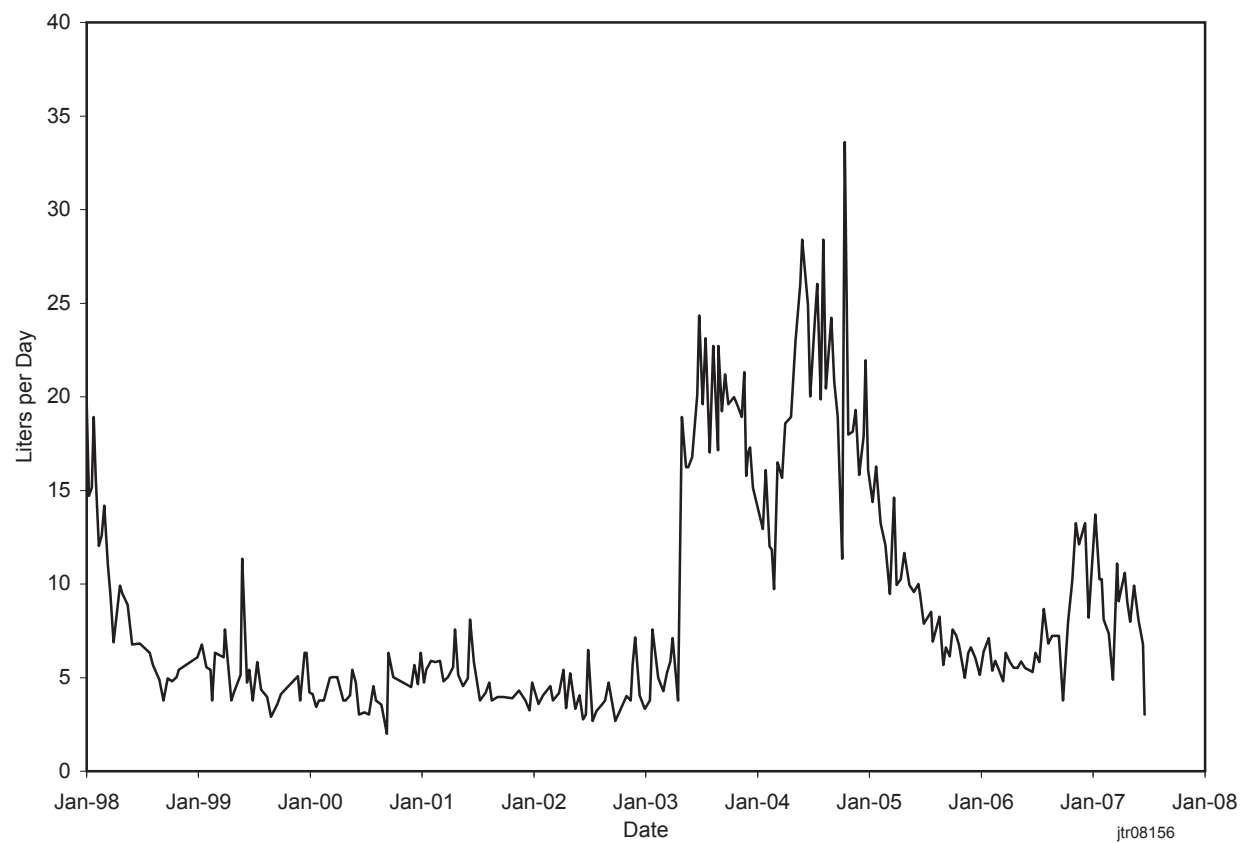


Figure 3.0-1 Leachate Collection Volumes at the 600 Area Central Landfill



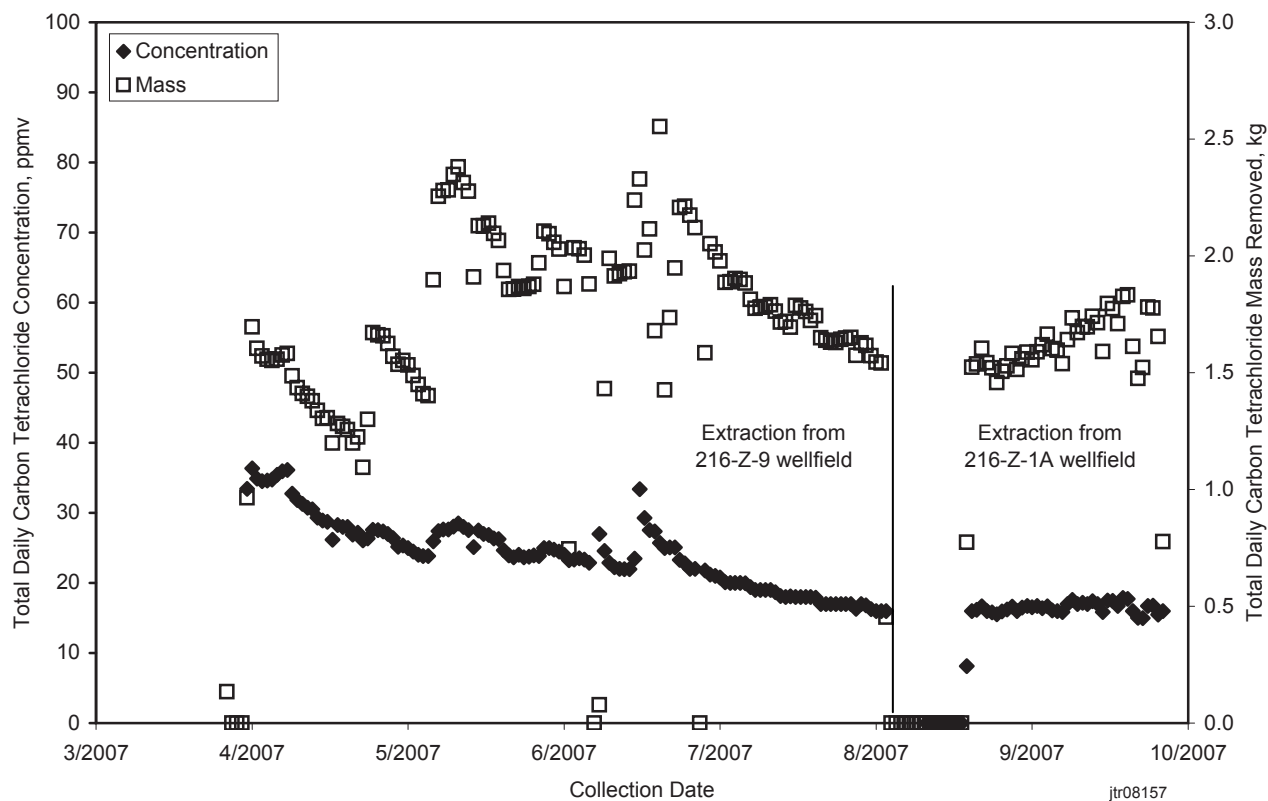


Figure 3.0-3. Time Series Concentrations and Mass of Carbon Tetrachloride in Soil Vapor Extracted from 216-Z-1A/216-Z-12/216-Z-18 and 216-Z-9 Well Fields

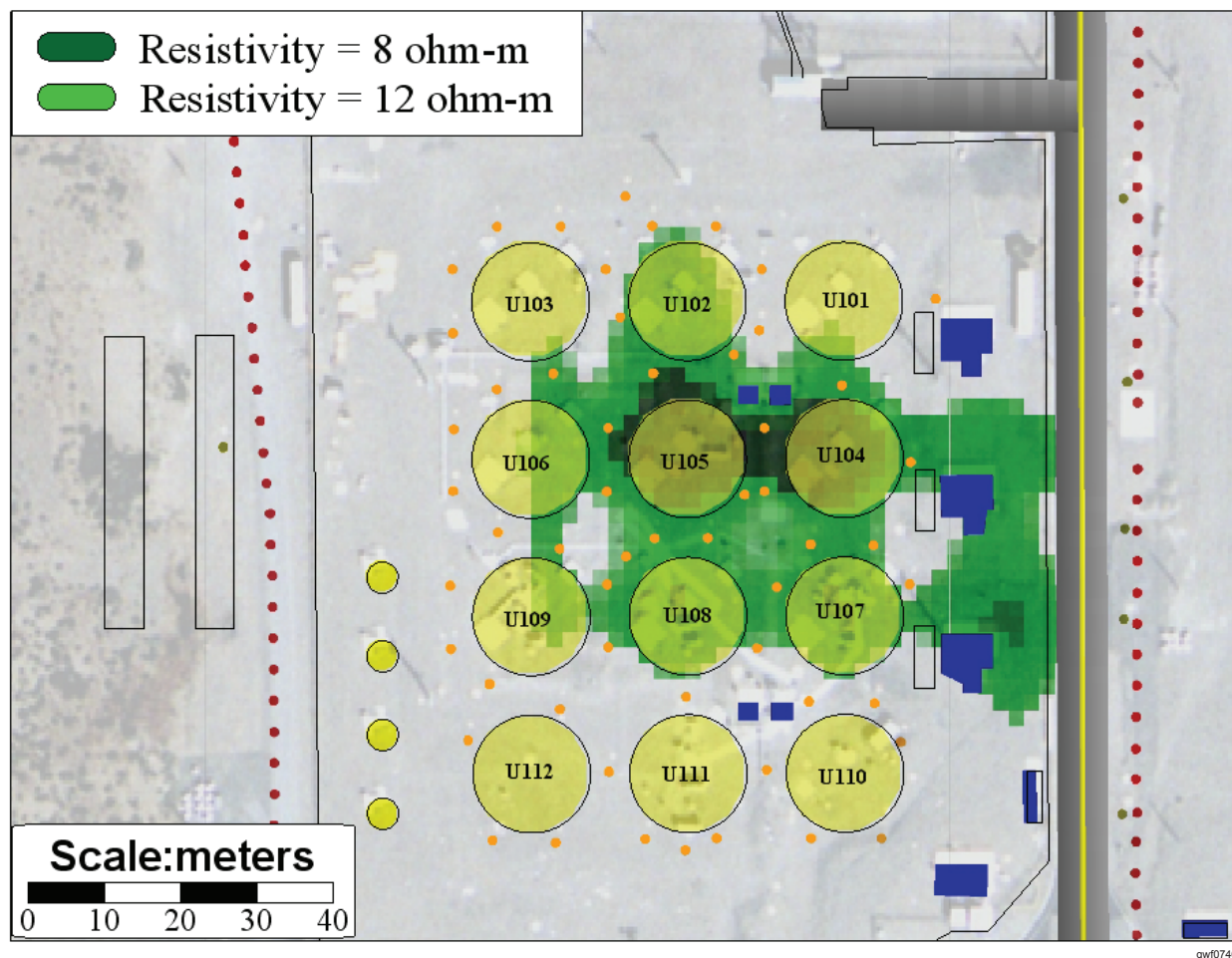


Figure 3.0-4. Resistivity Anomalies Associated with the B Tank Farm Complex

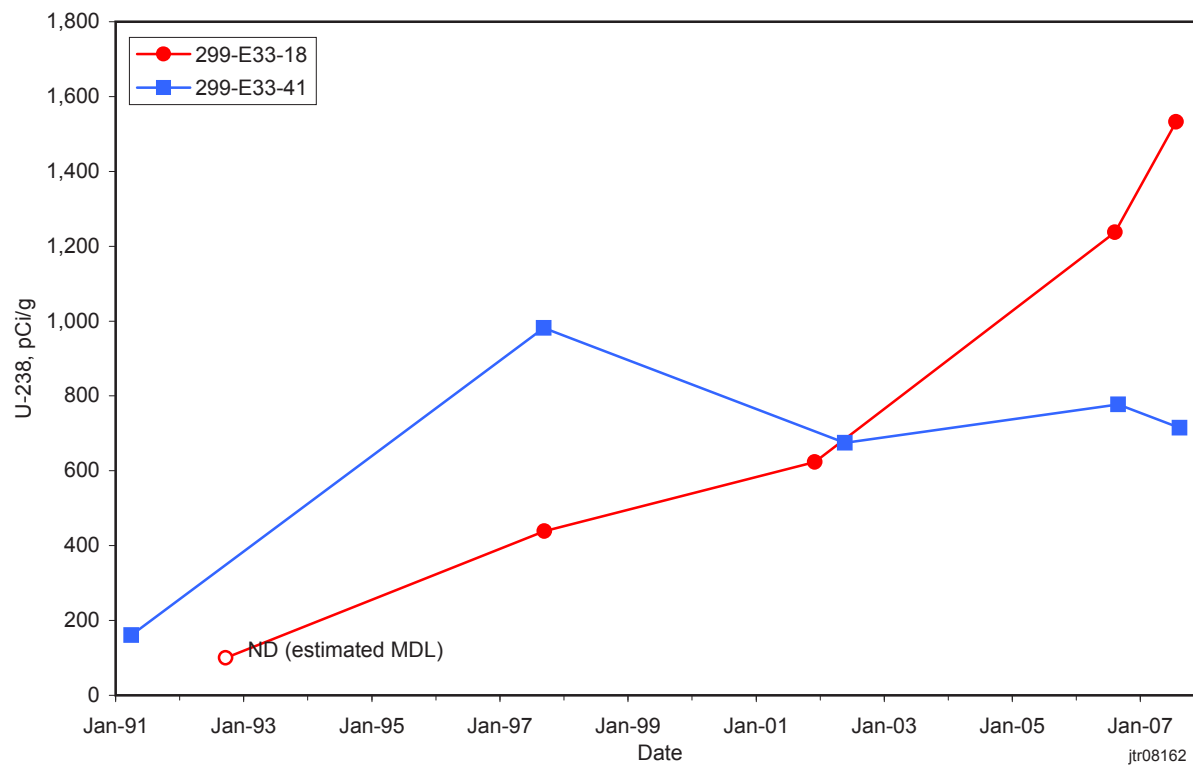


Figure 3.0-5. Deep Vadose Zone Uranium-238 in Wells 299-E33-18 and 299-E33-41
(Construction information for these wells can be found at
<http://www.hanford.gov/cp/gpp/data/vzcp/data/200East.cfm>.)